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(71) Applicant: DEGUSSA AG [DE/DE]; Bennigseplatz 1, 40474 Düsseldorf (DE).

(72) Inventors: RIEPING, Mechthild; Mönkebergstrasse 1, 33619 Bielefeld (DE). THIERBACH, Georg; Gunststrasse 21, 33613 Bielefeld (DE).

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(54) Title: PROCESS FOR THE FERMENTATIVE PREPARATION OF L-AMINO ACIDS USING STRAINS OF THE ENTEROBACTERIACEAE FAMILY

(57) Abstract: The invention relates to a process for the fermentative preparation of L-amino acids, in particular L-threonine, in which the following steps are carried out: a) fermentation of the microorganisms of the Enterobacteriaceae family which produce the desired L-amino acid and in which at least the *poxB* gene or nucleotide sequences which code for it are attenuated, in particular eliminated, b) concentration of the L-amino acid in the medium or in the cells of the bacteria and c) isolation of the L-amino acid.

**Process for the fermentative preparation of L-amino acids
using strains of the Enterobacteriaceae family**

This invention relates to a process for the fermentative preparation of L-amino acids, in particular L-threonine,
5 L-lysine and L-valine, using strains of the Enterobacteriaceae family in which the poxB gene is attenuated.

Prior Art

L-Amino acids, in particular L-threonine, L-lysine and
10 L-valine are used in human medicine and in the pharmaceuticals industry, in the foodstuffs industry and very particularly in animal nutrition.

It is known to prepare L-amino acids by fermentation of strains of Enterobacteriaceae, in particular Escherichia
15 coli (E. coli) and Serratia marcescens. Because of their great importance, work is constantly being undertaken to improve the preparation processes. Improvements to the process can relate to fermentation measures, such as e.g. stirring and supply of oxygen, or the composition of the
20 nutrient media, such as e.g. the sugar concentration during the fermentation, or the working up to the product form, by e.g. ion exchange chromatography, or the intrinsic output properties of the microorganism itself.

Methods of mutagenesis, selection and mutant selection are
25 used to improve the output properties of these microorganisms. Strains which are resistant to antimetabolites, such as e.g. the threonine analogue α -amino- β -hydroxyvaleric acid (AHV), or are auxotrophic for metabolites of regulatory importance and produce L-amino
30 acid, such as e.g. L-threonine, are obtained in this manner.

Methods of the recombinant DNA technique have also been employed for some years for improving the strain of

strains of the Enterobacteriaceae family which produce L-amino acids, by amplifying individual amino acid biosynthesis genes and investigating the effect on the production.

5 Object of the Invention

The inventors had the object of providing new measures for improved fermentative preparation of L-amino acids, in particular L-threonine, L-lysine and L-valine.

Description of the Invention

- 10 The invention provides a process for the fermentative preparation of L-amino acids, in particular L-threonine, using microorganisms of the Enterobacteriaceae family which, in particular, already produce L-threonine and in which the nucleotide sequence which codes for the enzyme
15 pyruvate oxidase (EC 1.2.2.2) (poxB gene) is attenuated.

The term "attenuation" in this connection describes the reduction or elimination of the intracellular activity of one or more enzymes (proteins) in a microorganism which are coded by the corresponding DNA, for example by using a weak
20 promoter or a gene or allele which codes for a corresponding enzyme with a low activity or inactivates the corresponding enzyme (protein) or gene, and optionally combining these measures.

The process comprises carrying out the following steps:

- 25 a) fermentation of microorganisms of the Enterobacteriaceae family in which at least the poxB gene is attenuated,
b) concentration of the corresponding L-amino acid in the medium or in the cells of the microorganisms of
30 the Enterobacteriaceae family, and
c) isolation of the desired L-amino acid.

The microorganisms which the present invention provides can produce L-amino acids from glucose, sucrose, lactose, fructose, maltose, molasses, optionally starch, optionally cellulose or from glycerol and ethanol. They are
5 representatives of the Enterobacteriaceae family chosen from the genera *Escherichia*, *Erwinia*, *Providencia* and *Serratia*. The genera *Escherichia* and *Serratia* are preferred. Of the genus *Escherichia* the species *Escherichia coli* and of the genus *Serratia* the species *Serratia*
10 *marcescens* are to be mentioned in particular.

Suitable strains, which produce L-threonine in particular, of the genus *Escherichia*, in particular of the species *Escherichia coli*, are, for example

15 *Escherichia coli* TF427
Escherichia coli H4578
Escherichia coli KY10935
Escherichia coli VNIIGenetika MG442
Escherichia coli VNIIGenetika M1
Escherichia coli VNIIGenetika 472T23
20 *Escherichia coli* BKIIM B-3996
Escherichia coli kat 13
Escherichia coli KCCM-10132

Suitable L-threonine-producing strains of the genus *Serratia*, in particular of the species *Serratia marcescens*,
25 are, for example

Serratia marcescens HNr21
Serratia marcescens TLr156
Serratia marcescens T2000.

Strains from the Enterobacteriaceae family which produce
30 L-threonine preferably have, inter alia, one or more genetic or phenotypic features chosen from the group consisting of: resistance to α -amino- β -hydroxyvaleric acid, resistance to thialysine, resistance to ethionine,

- resistance to α -methylserine, resistance to diaminosuccinic acid, resistance to α -aminobutyric acid, resistance to borrelidin, resistance to rifampicin, resistance to valine analogues, such as, for example, valine hydroxamate,
- 5 resistance to purine analogues, such as, for example, 6-dimethylaminopurine, a need for L-methionine, optionally a partial and compensatable need for L-isoleucine, a need for meso-diaminopimelic acid, auxotrophy in respect of threonine-containing dipeptides, resistance to L-threonine,
- 10 resistance to L-homoserine, resistance to L-lysine, resistance to L-methionine, resistance to L-glutamic acid, resistance to L-aspartate, resistance to L-leucine, resistance to L-phenylalanine, resistance to L-serine, resistance to L-cysteine, resistance to L-valine,
- 15 sensitivity to fluoropyruvate, defective threonine dehydrogenase, optionally a capacity for sucrose utilization, enhancement of the threonine operon, enhancement of homoserine dehydrogenase I-aspartate kinase I, preferably of the feedback-resistant form, enhancement
- 20 of homoserine kinase, enhancement of threonine synthase, enhancement of aspartate kinase, optionally of the feedback-resistant form, enhancement of aspartate semialdehyde dehydrogenase, enhancement of phosphoenol pyruvate carboxylase, optionally of the feedback-resistant
- 25 form, enhancement of phosphoenol pyruvate synthase, enhancement of transhydrogenase, enhancement of the RhtB gene product, enhancement of the RhtC gene product, enhancement of the YfiK gene product, enhancement of a pyruvate carboxylase, and attenuation of acetic acid
- 30 formation.

It has been found that microorganisms of the Enterobacteriaceae family produce L-amino acids, in particular L-threonine, in an improved manner after attenuation, in particular elimination, of the poxB gene,

35 which codes for pyruvate oxidase (EC number 1.2.2.2).

It has furthermore been found that microorganisms of the Enterobacteriaceae family form lower concentrations of the undesirable by-product acetic acid after attenuation, in particular elimination, of the *poxB* gene, which codes for
5 pyruvate oxidase (EC number 1.2.2.2).

The nucleotide sequence of the *poxB* gene of *Escherichia coli* has been published by Grabau and Cronan (Nucleic Acids Research. 14 (13), 5449-5460 (1986)) and can also be found from the genome sequence of *Escherichia coli* published by
10 Blattner et al. (Science 277, 1453 - 1462 (1997)), under Accession Number AE000188. The nucleotide sequence of the *poxB* gene of *Escherichia coli* is shown in SEQ ID No. 1 and the amino acid sequence of the associated gene product is shown in SEQ ID No. 2.

15 The *poxB* genes described in the text references mentioned can be used according to the invention. Alleles of the *poxB* gene which result from the degeneracy of the genetic code or due to "sense mutations" of neutral function can furthermore be used.

20 To achieve an attenuation, for example, expression of the *poxB* gene or the catalytic properties of the enzyme protein can be reduced or eliminated. The two measures can optionally be combined.

The reduction in gene expression can take place by suitable
25 culturing, by genetic modification (mutation) of the signal structures of gene expression or also by the antisense-RNA technique. Signal structures of gene expression are, for example, repressor genes, activator genes, operators, promoters, attenuators, ribosome binding sites, the start
30 codon and terminators. The expert can find information in this respect, inter alia, for example, in Jensen and Hammer (Biotechnology and Bioengineering 58: 191-195 (1998)), in Carrier and Keasling (Biotechnology Progress 15, 58-64 (1999)), Franch and Gerdes (Current Opinion in Microbiology

3, 159-164 (2000)) and in known textbooks of genetics and molecular biology, such as, for example, the textbook of Knippers ("Molekulare Genetik [Molecular Genetics]", 6th edition, Georg Thieme Verlag, Stuttgart, Germany, 1995) or
5 that of Winnacker ("Gene und Klone [Genes and Clones]", VCH Verlagsgesellschaft, Weinheim, Germany, 1990).

Mutations which lead to a change or reduction in the catalytic properties of enzyme proteins are known from the prior art. Examples which may be mentioned are the works of
10 Qiu and Goodman (Journal of Biological Chemistry 272: 8611-8617 (1997)), Yano et al. (Proceedings of the National Academy of Sciences, USA 95, 5511-5515 (1998)), Wentz and Schachmann (Journal of Biological Chemistry 266, 20833-20839 (1991)). Summarizing descriptions can be found in
15 known textbooks of genetics and molecular biology, such as e.g. that by Hagemann ("Allgemeine Genetik ", Gustav Fischer Verlag, Stuttgart, 1986).

Possible mutations are transitions, transversions, insertions and deletions. Depending on the effect of the
20 amino acid exchange on the enzyme activity, "missense mutations" or "nonsense mutations" are referred to. Insertions or deletions of at least one base pair in a gene lead to "frame shift mutations", which lead to incorrect amino acids being incorporated or translation being
25 interrupted prematurely. Deletions of several codons typically lead to a complete loss of the enzyme activity. Instructions on generation of such mutations are prior art and can be found in known textbooks of genetics and molecular biology, such as e.g. the textbook by Knippers
30 ("Molekulare Genetik [Molecular Genetics]", 6th edition, Georg Thieme Verlag, Stuttgart, Germany, 1995), that by Winnacker ("Gene und Klone ", VCH Verlagsgesellschaft, Weinheim, Germany, 1990) or that by Hagemann ("Allgemeine Genetik ", Gustav Fischer Verlag, Stuttgart, 1986).

An example of a plasmid with the aid of which the *poxB* gene of *Escherichia coli* can be attenuated, in particular eliminated, by position-specific mutagenesis is the plasmid pMAK705 Δ *poxB* (figure 1). In addition to residues of polylinker sequences, it contains only a part of the 5' and a part of the 3' region of the *poxB* gene. A 340 bp long section of the coding region is missing (deletion). The sequence of this DNA which can be employed for mutagenesis of the *poxB* gene is shown in SEQ ID No. 3.

- 10 The deletion mutation of the *poxB* gene can be incorporated into suitable strains by gene or allele replacement.

A conventional method is the method, described by Hamilton et al. (Journal of Bacteriology 174, 4617 - 4622 (1989)), of gene replacement with the aid of a conditionally replicating pSC101 derivative pMAK705. Other methods described in the prior art, such as, for example, those of Martinez-Morales et al. (Journal of Bacteriology 1999, 7143-7148 (1999)) or those of Boyd et al. (Journal of Bacteriology 182, 842-847 (2000)), can likewise be used.

- 20 After replacement has taken place, the strain in question contains the form of the Δ *poxB* allele shown in SEQ ID No. 4, which is also provided by the invention.

It is also possible to transfer mutations in the *poxB* gene or mutations which affect expression of the *poxB* gene into various strains by conjugation or transduction.

- It may furthermore be advantageous for the production of L-amino acids, in particular L-threonine, with strains of the Enterobacteriaceae family to enhance one or more enzymes of the known threonine biosynthesis pathway or enzymes of anaplerotic metabolism or enzymes for the production of reduced nicotinamide adenine dinucleotide phosphate, in addition to the attenuation of the *poxB* gene.
- 30

The term "enhancement" in this connection describes the increase in the intracellular activity of one or more enzymes or proteins in a microorganism which are coded by the corresponding DNA, for example by increasing the number
5 of copies of the gene or genes, using a potent promoter or a gene which codes for a corresponding enzyme or protein with a high activity, and optionally combining these measures.

Thus, for example, one or more genes chosen from the group
10 consisting of

- the thrABC operon which codes for aspartate kinase, homoserine dehydrogenase, homoserine kinase and threonine synthase (US-A-4,278,765),
- the pyc gene which codes for pyruvate carboxylase
15 (DE-A-19 831 609),
- the pps gene which codes for phosphoenol pyruvate synthase (Molecular and General Genetics 231:332 1992)),
- the ppc gene which codes for phosphoenol pyruvate carboxylase (Gene 31:279-283 (1984)),
- 20 • the pntA and pntB genes which code for transhydrogenase (European Journal of Biochemistry 158:647-653 (1986)),
- the rhtB gene which imparts homoserine resistance (EP-A-0 994 190),
- the mgo gene which codes for malate:quinone
25 oxidoreductase (DE 100 348 33.5),
- the rhtC gene which imparts threonine resistance (EP-A-1 013 765), and
- the thrE gene of Corynebacterium glutamicum which codes for threonine export (DE 100 264 94.8) and

- the *gdhA* gene which codes for glutamate dehydrogenase (Nucleic Acids Research 11: 5257-5266 (1983); Gene 23: 199-209 (1983))

can be enhanced, in particular over-expressed, at the same
5 time.

It may furthermore be advantageous for the production of L-amino acids, in particular threonine, in addition to the attenuation of the *poxB* gene, for one or more genes chosen from the group consisting of

- 10 • the *tdh* gene which codes for threonine dehydrogenase (Ravnikar and Somerville, Journal of Bacteriology 169, 4716-4721 (1987)),
- the *mdh* gene which codes for malate dehydrogenase (E.C. 1.1.1.37) (Vogel et al., Archives in Microbiology 149,
15 36-42 (1987)),
- the gene product of the open reading frame (orf) *yjfa* (Accession Number AAC77180 of the National Center for Biotechnology Information (NCBI, Bethesda, MD, USA),
- 20 • the gene product of the open reading frame (orf) *ytfP* (Accession Number AAC77179 of the National Center for Biotechnology Information (NCBI, Bethesda, MD, USA) and
- the *pckA* gene which codes for the enzyme phosphoenol pyruvate carboxykinase (Medina et al. (Journal of Bacteriology 172, 7151-7156 (1990))
- 25 to be attenuated, in particular eliminated or reduced in expression.

In addition to attenuation of the *poxB* gene it may furthermore be advantageous for the production of L-amino acids, in particular L-threonine, to eliminate undesirable
30 side reactions (Nakayama: "Breeding of Amino Acid Producing Microorganisms", in: Overproduction of Microbial Products,

Krumphanzl, Sikyta, Vanek (eds.), Academic Press, London, UK, 1982).

The microorganisms produced according to the invention can be cultured in the batch process (batch culture), the fed
5 batch (feed process) or the repeated fed batch process (feed process). A summary of known culture methods is described in the textbook by Chmiel (Bioprozesstechnik 1. Einführung in die Bioverfahrenstechnik [Bioprocess
Technology 1. Introduction to Bioprocess Technology (Gustav
10 Fischer Verlag, Stuttgart, 1991)) or in the textbook by Storhas (Bioreaktoren und periphere Einrichtungen (Vieweg Verlag, Braunschweig/Wiesbaden, 1994)).

The culture medium to be used must meet the requirements of the particular strains in a suitable manner. Descriptions
15 of culture media for various microorganisms are contained in the handbook "Manual of Methods for General Bacteriology" of the American Society for Bacteriology (Washington D.C., USA, 1981).

Sugars and carbohydrates, such as e.g. glucose, sucrose,
20 lactose, fructose, maltose, molasses, starch and optionally cellulose, oils and fats, such as e.g. soya oil, sunflower oil, groundnut oil and coconut fat, fatty acids, such as e.g. palmitic acid, stearic acid and linoleic acid, alcohols, such as e.g. glycerol and ethanol, and organic
25 acids, such as e.g. acetic acid, can be used as the source of carbon. These substances can be used individually or as a mixture.

Organic nitrogen-containing compounds, such as peptones, yeast extract, meat extract, malt extract, corn steep
30 liquor, soya bean flour and urea, or inorganic compounds, such as ammonium sulfate, ammonium chloride, ammonium phosphate, ammonium carbonate and ammonium nitrate, can be used as the source of nitrogen. The sources of nitrogen can be used individually or as a mixture.

Phosphoric acid, potassium dihydrogen phosphate or dipotassium hydrogen phosphate or the corresponding sodium-containing salts can be used as the source of phosphorus. The culture medium must furthermore comprise salts of
5 metals, such as e.g. magnesium sulfate or iron sulfate, which are necessary for growth. Finally, essential growth substances, such as amino acids and vitamins, can be employed in addition to the abovementioned substances. Suitable precursors can moreover be added to the culture
10 medium. The starting substances mentioned can be added to the culture in the form of a single batch, or can be fed in during the culture in a suitable manner.

Basic compounds, such as sodium hydroxide, potassium hydroxide, ammonia or aqueous ammonia, or acid compounds,
15 such as phosphoric acid or sulfuric acid, can be employed in a suitable manner to control the pH. Antifoams, such as e.g. fatty acid polyglycol esters, can be employed to control the development of foam. Suitable substances having a selective action, e.g. antibiotics, can be added
20 to the medium to maintain the stability of plasmids. To maintain aerobic conditions, oxygen or oxygen-containing gas mixtures, such as e.g. air, are introduced into the culture. The temperature of the culture is usually 25°C to 45°C, and preferably 30°C to 40°C. Culturing is continued
25 until a maximum of L-amino acids or L-threonine has formed. This target is usually reached within 10 hours to 160 hours.

The analysis of L-amino acids can be carried out by anion exchange chromatography with subsequent ninhydrin
30 derivatization, as described by Spackman et al. (Analytical Chemistry, 30, (1958), 1190), or it can take place by reversed phase HPLC as described by Lindroth et al. (Analytical Chemistry (1979) 51: 1167-1174).

A pure culture of the Escherichia coli K-12 strain
35 DH5 α /pMAK705 was deposited as DSM 13720 on 8th September

2000 at the Deutsche Sammlung für Mikroorganismen und Zellkulturen (DSMZ = German Collection of Microorganisms and Cell Cultures, Braunschweig, Germany) in accordance with the Budapest Treaty.

- 5 A pure culture of the Escherichia coli K-12 strain MG442ApoxB was deposited as DSM 13762 on 2nd October 2000 at the Deutsche Sammlung für Mikroorganismen und Zellkulturen (DSMZ = German Collection of Microorganisms and Cell Cultures, Braunschweig, Germany) in accordance
10 with the Budapest Treaty.

The process according to the invention is used for the fermentative preparation of L-amino acids, such as e.g. L-thrèonine, L-isoleucine, L-valine, L-methionine, L-homoserine and L-lysine, in particular L-threonine.

- 15 The present invention is explained in more detail in the following with the aid of embodiment examples.

- The isolation of plasmid DNA from Escherichia coli and all techniques of restriction, Klenow and alkaline phosphatase treatment are carried out by the method of Sambrook et al.
20 (Molecular cloning - A laboratory manual (1989) Cold Spring Harbour Laboratory Press). Unless described otherwise, the transformation of Escherichia coli is carried out by the method of Chung et al. (Proceedings of the National Academy of Sciences of the United States of America USA (1989) 86:
25 2172-2175).

The incubation temperature for the preparation of strains and transformants is 37°C. Temperatures of 30°C and 44°C are used in the gene replacement method of Hamilton et. al.

Example 1

Construction of the deletion mutation of the poxB gene

Parts of the 5' and 3' region of the poxB gene are amplified from Escherichia coli K12 using the polymerase chain reaction (PCR) and synthetic oligonucleotides. Starting from the nucleotide sequence of the poxB gene in E. coli K12 MG1655 (SEQ ID No. 1), the following PCR primers are synthesized (MWG Biotech, Ebersberg, Germany):

poxB'5'-1: 5' - CTGAACGGTCTTAGTGACAG - 3'

10 poxB'5'-2: 5' - AGGCCTGGAATAACGCAGCAGTTG - 3'

poxB'3'-1: 5' - CTGCGTGCATTGCTTCCATTG - 3'

poxB'3'-2: 5' - GCCAGTTCGATCACTTCATCAC - 3'

The chromosomal E. coli K12 MG1655 DNA employed for the PCR is isolated according to the manufacturers instructions with "Qiagen Genomic-tips 100/G" (QIAGEN, Hilden, Germany). A DNA fragment approx. 500 base pairs (bp) in size from the 5' region of the poxB gene (called poxB1) and a DNA fragment approx. 750 bp in size from the 3' region of the poxB gene (called poxB2) can be amplified with the specific primers under standard PCR conditions (Innis et al. (1990) PCR Protocols. A Guide to Methods and Applications, Academic Press) with Taq-DNA polymerase (Gibco-BRL, Eggenstein, Germany). The PCR products are each ligated with the vector pCR2.1TOPO (TOPO TA Cloning Kit, Invitrogen, Groningen, The Netherlands) in accordance with the manufacturers instructions and transformed into the E. coli strain TOP10F'.

Selection of plasmid-carrying cells takes place on LB agar, to which 50 µg/ml ampicillin are added. After isolation of the plasmid DNA, the vector pCR2.1TOPOpoxB1 is cleaved with the restriction enzymes Ecl136II and XbaI and, after

separation in 0.8% agarose gel, the *poxB1* fragment is isolated with the aid of the QIAquick Gel Extraction Kit (QIAGEN, Hilden, Germany). After isolation of the plasmid DNA the vector pCR2.1TOPO Δ *poxB2* is cleaved with the enzymes
5 *EcoRV* and *XbaI* and ligated with the *poxB1* fragment isolated. The *E. coli* strain DH5 α is transformed with the ligation batch and plasmid-carrying cells are selected on LB agar, to which 50 μ g/ml ampicillin is added. After
10 isolation of the plasmid DNA those plasmids in which the mutagenic DNA sequence shown in SEQ ID No. 3 is cloned are detected by control cleavage with the enzymes *HindIII* and *XbaI*. One of the plasmids is called pCR2.1TOPO Δ *poxB*.

Example 2

Construction of the replacement vector pMAK705 Δ *poxB*

15 The *poxB* allele described in Example 1 is isolated from the vector pCR2.1TOPO Δ *poxB* after restriction with the enzymes *HindIII* and *XbaI* and separation in 0.8% agarose gel, and ligated with the plasmid pMAK705 (Hamilton et al. (1989) *Journal of Bacteriology* 174, 4617 - 4622), which has been
20 digested with the enzymes *HindIII* and *XbaI*. The ligation batch is transformed in DH5 α and plasmid-carrying cells are selected on LB agar, to which 20 μ g/ml chloramphenicol is added. Successful cloning is demonstrated after isolation of the plasmid DNA and cleavage with the enzymes *HindIII*
25 and *XbaI*. The replacement vector formed, pMAK705 Δ *poxB* (= pMAK705 Δ *poxB*), is shown in figure 1.

Example 3

Position-specific mutagenesis of the *poxB* gene in the *E. coli* strain MG442

30 The L-threonine-producing *E. coli* strain MG442 is described in the patent specification US-A- 4,278,765 and deposited as CMIM B-1628 at the Russian National Collection for Industrial Microorganisms (VKPM, Moscow, Russia).

For replacement of the chromosomal *poxB* gene with the plasmid-coded deletion construct, MG442 is transformed with the plasmid pMAK705 Δ *poxB*. The gene replacement is carried out by the selection method described by Hamilton et al.

- 5 (1989) Journal of Bacteriology 174, 4617 - 4622) and is verified by standard PCR methods (Innis et al. (1990) PCR Protocols. A Guide to Methods and Applications, Academic Press) with the following oligonucleotide primers:

poxB'5'-1: 5' - CTGAACGGTCTTAGTGACAG - 3'

- 10 *poxB*'3'-2: 5' - GCCAGTTCGATCACTTCATCAC -3'

The strain obtained is called MG442 Δ *poxB*.

Example 4

Preparation of L-threonine with the strain MG442 Δ *poxB*

- MG442 Δ *poxB* is multiplied on minimal medium with the
15 following composition: 3.5 g/l Na₂HPO₄*2H₂O, 1.5 g/l KH₂PO₄, 1 g/l NH₄Cl, 0.1 g/l MgSO₄*7H₂O, 2 g/l glucose, 20 g/l agar. The formation of L-threonine is checked in batch cultures of 10 ml contained in 100 ml conical flasks. For this, 10 ml of preculture medium of the following composition:
20 2 g/l yeast extract, 10 g/l (NH₄)₂SO₄, 1 g/l KH₂PO₄, 0.5 g/l MgSO₄*7H₂O, 15 g/l CaCO₃, 20 g/l glucose are inoculated and the batch is incubated for 16 hours at 37°C and 180 rpm on an ESR incubator from Kühner AG (Birsfelden, Switzerland). 250 μ l of this preculture are transinoculated into 10 ml of
25 production medium (25 g/l (NH₄)₂SO₄, 2 g/l KH₂PO₄, 1 g/l MgSO₄*7H₂O, 0.03 g/l FeSO₄*7H₂O, 0.018 g/l MnSO₄*1H₂O, 30 g/l CaCO₃, 20 g/l glucose) and the batch is incubated for 48 hours at 37°C. After the incubation the optical density (OD) of the culture suspension is determined with an LP2W
30 photometer from Dr. Lange (Berlin, Germany) at a measurement wavelength of 660 nm.

The concentration of L-threonine formed is then determined in the sterile-filtered culture supernatant with an amino acid analyzer from Eppendorf-BioTronik (Hamburg, Germany) by ion exchange chromatography and post-column reaction
5 with ninhydrin detection.

The result of the experiment is shown in Table 1.

Table 1

| Strain | OD (660 nm) | L-Threonine g/l |
|------------|----------------|--------------------|
| MG442 | 6.0 | 1.5 |
| MG442ΔpoxB | 4.9 | 2.6 |

Example 5

- 10 Preparation of L-threonine with the strain
MG442ΔpoxB/pMW218gdhA

5.1 Amplification and cloning of the *gdhA* gene

The glutamate dehydrogenase gene from *Escherichia coli* K12 is amplified using the polymerase chain reaction (PCR) and
15 synthetic oligonucleotides. Starting from the nucleotide sequence for the *gdhA* gene in *E. coli* K12 MG1655 (gene library: Accession No. AE000270 and No. AE000271), PCR primers are synthesized (MWG Biotech, Ebersberg, Germany):

Gdh1: 5' - TGAACACTTCTGGCGGTACG - 3'

- 20 Gdh2: 5' - CCTCGGCGAAGCTAATATGG - 3'

The chromosomal *E. coli* K12 MG1655 DNA employed for the PCR is isolated according to the manufacturers instructions with "QIAGEN Genomic-tips 100/G" (QIAGEN, Hilden, Germany). A DNA fragment approx. 2150 bp in size, which comprises the

- gdhA coding region and approx. 350 bp 5'-flanking and approx. 450 bp 3'-flanking sequences, can be amplified with the specific primers under standard PCR conditions (Innis et al.: PCR protocols. A guide to methods and applications, 1990, Academic Press) with Pfu-DNA polymerase (Promega Corporation, Madison, USA). The PCR product is cloned in the plasmid pCR2.1TOPO and transformed in the E. coli strain TOP10 (Invitrogen, Leek, The Netherlands, Product Description TOPO TA Cloning Kit, Cat. No. K4500-01).
- 10 Successful cloning is demonstrated by cleavage of the plasmid pCR2.1TOPOgdhA with the restriction enzymes EcoRI and EcoRV. For this, the plasmid DNA is isolated by means of the "QIAprep Spin Plasmid Kit" (QIAGEN, Hilden, Germany) and, after cleavage, separated in a 0.8% agarose gel.
- 15 5.2 Cloning of the gdhA gene in the plasmid vector pMW218

- The plasmid pCR2.1TOPOgdhA is cleaved with the enzyme EcoRI, the cleavage batch is separated on 0.8% agarose gel and the gdhA fragment 2.1 kbp in size is isolated with the aid of the "QIAquick Gel Extraction Kit" (QIAGEN, Hilden, Germany). The plasmid pMW218 (Nippon Gene, Toyama, Japan) is cleaved with the enzyme EcoRI and ligated with the gdhA fragment. The E. coli strain DH5 α is transformed with the ligation batch and pMW218-carrying cells are selected by plating out on LB agar (Lennox, Virology 1955, 1: 190), to which 20 μ g/ml kanamycin are added.
- 20
- 25

Successful cloning of the gdhA gene can be demonstrated after plasmid DNA isolation and control cleavage with EcoRI and EcoRV. The plasmid is called pMW218gdhA (figure 2).

5.3 Preparation of the strain MG442 Δ poxB/pMW218gdhA

- 30 The strain MG442 Δ poxB obtained in Example 3 and the strain MG442 are transformed with the plasmid pMW218gdhA and transformants are selected on LB agar, which is supplemented with 20 μ g/ml kanamycin. The strains

MG442 Δ poxB/pMW218gdhA and MG442/pMW218gdhA are formed in this manner.

5.4 Preparation of L-threonine

The preparation of L-threonine by the strains

- 5 MG442 Δ poxB/pMW218gdhA and MG442/pMW218gdhA is tested as described in Example 4. The minimal medium and the preculture medium are additionally supplemented with 20 μ g/ml kanamycin for these two strains.

The result of the experiment is summarized in Table 2.

10

Table 2

| Strain | OD (660 nm) | L-Threonine g/l |
|--------------------------------|----------------|--------------------|
| MG442 | 6.0 | 1.5 |
| MG442 Δ poxB | 4.9 | 2.6 |
| MG442/pMW218gdhA | 5.6 | 2.6 |
| MG442 Δ poxB/pMW218gdhA | 5.5 | 2.9 |

Example 6

Preparation of L-threonine with the strain
MG442 Δ poxB/pMW219rhtC

15 6.1 Amplification of the rhtC gene

The rhtC gene from Escherichia coli K12 is amplified using the polymerase chain reaction (PCR) and synthetic oligonucleotides. Starting from the nucleotide sequence for the rhtC gene in E. coli K12 MG1655 (gene library:

20 Accession No. AE000458, Zakataeva et al. (FEBS Letters 452,

228-232 (1999)), PCR primers are synthesized (MWG Biotech, Ebersberg, Germany):

RhtC1: 5' - CTGTTAGCATCGGCGAGGCA - 3'

RhtC2: 5' - GCATGTTGATGGCGATGACG - 3'

- 5 The chromosomal E. coli K12 MG1655 DNA employed for the PCR is isolated according to the manufacturers instructions with "QIAGEN Genomic-tips 100/G" (QIAGEN, Hilden, Germany). A DNA fragment approx. 800 bp in size can be amplified with the specific primers under standard PCR conditions (Innis et al.: PCR protocols. A guide to methods and applications, 1990, Academic Press) with Pfu-DNA polymerase (Promega Corporation, Madison, USA).

6.2 Cloning of the rhtC gene in the plasmid vector pMW219

- The plasmid pMW219 (Nippon Gene, Toyama, Japan) is cleaved with the enzyme SamI and ligated with the rhtC-PCR fragment. The E. coli strain DH5 α is transformed with the ligation batch and pMW219-carrying cells are selected on LB agar, which is supplemented with 20 μ g/ml kanamycin. Successful cloning can be demonstrated after plasmid DNA isolation and control cleavage with KpnI, HindIII and NcoI. The plasmid pMW219rhtC is shown in figure 3.

6.3 Preparation of the strain MG442 Δ poxB/pMW219rhtC

- The strain MG442 Δ poxB obtained in Example 3 and the strain MG442 are transformed with the plasmid pMW219rhtC and transformants are selected on LB agar, which is supplemented with 20 μ g/ml kanamycin. The strains MG442 Δ poxB/pMW219rhtC and MG442/pMW219rhtC are formed in this way.

6.4 Preparation of L-threonine

- 30 The preparation of L-threonine by the strains MG442 Δ poxB/pMW219rhtC and MG442/pMW219rhtC is tested as

described in Example 4. The minimal medium and the preculture medium are additionally supplemented with 20 µg/ml kanamycin for these two strains.

The result of the experiment is summarized in Table 3.

5

Table 3

| Strain | OD (660 nm) | L-Threonine g/l |
|-----------------------|----------------|--------------------|
| MG442 | 6.0 | 1.5 |
| MG442ΔpoxB | 4.9 | 2.6 |
| MG442/pMW219rhtC | 5.2 | 2.9 |
| MG442ΔpoxB/pMW219rhtC | 5.4 | 3.9 |

Example 7

Position-specific mutagenesis of the poxB gene in the E. coli strain TOC21R

- 10 The L-lysine-producing E. coli strain pDA1/TOC21R is described in the patent application F-A-2511032 and deposited at the Collection Nationale de Culture de Microorganisme (CNCM = National Microorganism Culture Collection, Pasteur Institute, Paris, France) under number
- 15 I-167. The strain and the plasmid-free host are also described by Dauce-Le Reverend et al. (European Journal of Applied Microbiology and Biotechnology 15:227-231 (1982)) under the name TOC21/pDA1.

- After culture in antibiotic-free LB medium for
- 20 approximately six generations, a derivative of strain pDA1/TOC21R which no longer contains the plasmid pDA1 is

isolated. The strain formed is tetracycline-sensitive and is called TOC21R.

For replacement of the chromosomal poxB gene with the plasmid-coded deletion construct, TOC21R is transformed
5 with the plasmid pMAK705 Δ poxB (Example 2). The gene replacement is carried out by the selection method described by Hamilton et al. (1989) Journal of Bacteriology 174, 4617 - 4622) and is verified by standard PCR methods (Innis et al. (1990) PCR Protocols. A Guide to Methods and
10 Applications, Academic Press) with the following oligonucleotide primers:

poxB'5'-1: 5' - CTGAACGGTCTTAGTGACAG - 3'

poxB'3'-2: 5' - GCCAGTTCGATCACTTCATCAC -3'

The strain obtained is called TOC21R Δ poxB.

15 Example 8

Preparation of L-lysine with the strain TOC21R Δ poxB

The formation of L-lysine by the strains TOC21R Δ poxB and TOC21R is checked in batch cultures of 10 ml contained in 100 ml conical flasks. For this, 10 ml of preculture medium
20 of the following composition: 2 g/l yeast extract, 10 g/l $(\text{NH}_4)_2\text{SO}_4$, 1 g/l KH_2PO_4 , 0.5 g/l $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 15 g/l CaCO_3 , 20 g/l glucose are inoculated and the batch is incubated for 16 hours at 37°C and 180 rpm on an ESR incubator from Kühner AG (Birsfelden, Switzerland). 250 μ l of this
25 preculture are transinoculated into 10 ml of production medium (25 g/l $(\text{NH}_4)_2\text{SO}_4$, 2 g/l KH_2PO_4 , 1 g/l $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 0.03 g/l $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, 0.018 g/l $\text{MnSO}_4 \cdot \text{H}_2\text{O}$, 30 g/l CaCO_3 , 20 g/l glucose, 25 mg/l L-isoleucine and 5 mg/l thiamine) and the batch is incubated for 72 hours at 37°C. After the
30 incubation the optical density (OD) of the culture suspension is determined with an LP2W photometer from Dr.

Lange (Berlin, Germany) at a measurement wavelength of 660 nm.

The concentration of L-lysine formed is then determined in the sterile-filtered culture supernatant with an amino acid analyzer from Eppendorf-BioTronik (Hamburg, Germany) by ion exchange chromatography and post-column reaction with ninhydrin detection.

The result of the experiment is shown in table 4.

Table 4

| Strain | OD (660 nm) | L-Lysine g/l |
|-------------|----------------|-----------------|
| TOC21R | 1.0 | 1.17 |
| TOC21RApoxB | 1.0 | 1.29 |

10

Example 9

Position-specific mutagenesis of the poxB gene in the E. coli strain B-1288

The L-valine-producing E. coli strain AJ 11502 is described in the patent specification US-A-4391907 and deposited at the National Center for Agricultural Utilization Research (Peoria, Illinois, USA) as NRRL B-12288.

After culture in antibiotic-free LB medium for approximately six generations, a plasmid-free derivative of strain AJ 11502 is isolated. The strain formed is ampicillin-sensitive and is called AJ11502kur.

For replacement of the chromosomal poxB gene with the plasmid-coded deletion construct, AJ11502kur is transformed with the plasmid pMAK705ΔpoxB (see Example 2). The gene replacement is carried out by the selection method

described by Hamilton et al. (1989) Journal of Bacteriology 174, 4617 - 4622) and is verified by standard PCR methods (Innis et al. (1990) PCR Protocols. A Guide to Methods and Applications, Academic Press) with the following
5 oligonucleotide primers:

poxB'5'-1: 5' - CTGAACGGTCTTAGTGACAG - 3'

poxB'3'-2: 5' - GCCAGTTCGATCACTTCATCAC -3'

The strain obtained is called AJ11502kurApoxB. The plasmid described in the patent specification US-A-4391907, which
10 carries the genetic information in respect of valine production, is isolated from strain NRRL B-12288. The strain AJ11502kurApoxB is transformed with this plasmid. One of the transformants obtained is called B-12288ApoxB.

Example 10

15 Preparation of L-valine with the strain B-12288ApoxB

The formation of L-valine by the strains B-12288ApoxB and NRRL B-12288 is checked in batch cultures of 10 ml contained in 100 ml conical flasks. For this, 10 ml of preculture medium of the following composition: 2 g/l yeast
20 extract, 10 g/l $(\text{NH}_4)_2\text{SO}_4$, 1 g/l KH_2PO_4 , 0.5 g/l $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 15 g/l CaCO_3 , 20 g/l glucose and 50 mg/l ampicillin are inoculated and the batch is incubated for 16 hours at 37°C and 180 rpm on an ESR incubator from Kühner AG (Birsfelden, Switzerland). 250 µl of this preculture are transinoculated
25 into 10 ml of production medium (25 g/l $(\text{NH}_4)_2\text{SO}_4$, 2 g/l KH_2PO_4 , 1 g/l $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 0.03 g/l $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, 0.018 g/l $\text{MnSO}_4 \cdot \text{H}_2\text{O}$, 30 g/l CaCO_3 , 20 g/l glucose, 5 mg/l thiamine and 50 mg/l ampicillin) and the batch is incubated for 72 hours at 37°C. After the incubation the optical density
30 (OD) of the culture suspension is determined with an LP2W photometer from Dr. Lange (Berlin, Germany) at a measurement wavelength of 660 nm.

The concentration of L-valine formed is then determined in the sterile-filtered culture supernatant with an amino acid analyzer from Eppendorf-BioTronik (Hamburg, Germany) by ion exchange chromatography and post-column reaction with
 5 ninhydrin detection.

The result of the experiment is shown in table 5.

Table 5

| Strain | OD (660 nm) | L-Valine g/l |
|-----------------------|----------------|-----------------|
| NRRL B-12288 | 5.7 | 0.95 |
| B-12288 Δ poxB | 5.6 | 1.05 |

Brief Description of the Figures

- 10 • Figure 1: pMAK705 Δ poxB (= pMAK705 Δ poxB)
 • Figure 2: pMW218gdhA
 • Figure 3: pMW219rhtC

The length data are to be understood as approx. data. The abbreviations and designations used have the following
 15 meaning:

- cat: chloramphenicol resistance gene
- rep-ts: temperature-sensitive replication region of the plasmid pSC101
- poxB1: part of the 5' region of the poxB gene
- 20 poxB2: part of the 3' region of the poxB gene
- kan: kanamycin resistance gene

gdhA: glutamate dehydrogenase gene
rhtC: gene imparting threonine resistance

The abbreviations for the restriction enzymes have the following meaning

- 5 • BamHI: restriction endonuclease from *Bacillus amyloliquefaciens*
- BglII: restriction endonuclease from *Bacillus globigii*
- ClaI: restriction endonuclease from *Caryophanon latum*
- 10 • Ecl136II restriction endonuclease from *Enterobacter cloacae* RFL136 (= Ecl136)
- EcoRI: restriction endonuclease from *Escherichia coli*
- EcoRV: restriction endonuclease from *Escherichia coli*
- HindIII: restriction endonuclease from *Haemophilus influenzae*
- 15 • KpnI: restriction endonuclease from *Klebsiella pneumoniae*
- PstI: restriction endonuclease from *Providencia stuartii*
- PvuI: restriction endonuclease from *Proteus vulgaris*
- 20 • SacI: restriction endonuclease from *Streptomyces achromogenes*
- SalI: restriction endonuclease from *Streptomyces albus*
- 25 • SmaI: restriction endonuclease from *Serratia marcescens*

- XbaI: restriction endonuclease from *Xanthomonas badrii*

XhoI: restriction endonuclease from *Xanthomonas holcicola*

BUDAPEST TREATY ON THE INTERNATIONAL
RECOGNITION OF THE DEPOSIT OF MICROORGANISMS
FOR THE PURPOSES OF PATENT PROCEDURE

INTERNATIONAL FORM

Degussa-Hüls AG
Kantstr. 2

33790 Halle

RECEIPT IN THE CASE OF AN ORIGINAL DEPOSIT
issued pursuant to Rule 7.1 by the
INTERNATIONAL DEPOSITARY AUTHORITY
Identified at the bottom of this page

| | |
|--|--|
| I. IDENTIFICATION OF THE MICROORGANISM | |
| Identification reference given by the DEPOSITOR: MG442ΔpoxB | Accession number given by the INTERNATIONAL DEPOSITARY AUTHORITY: DSM 13762 |
| II. SCIENTIFIC DESCRIPTION AND/OR PROPOSED TAXONOMIC DESIGNATION | |
| The microorganism identified under I. above was accompanied by: (X) a scientific description (X) a proposed taxonomic designation (Mark with a cross where applicable). | |
| III. RECEIPT AND ACCEPTANCE | |
| This International Depositary Authority accepts the microorganism identified under I. above, which was received by it on 2000-10-02 (Date of the original deposit) ¹ . | |
| IV. RECEIPT OF REQUEST FOR CONVERSION | |
| The microorganism identified under I above was received by this International Depositary Authority on (date of original deposit) and a request to convert the original deposit to a deposit under the Budapest Treaty was received by it on (date of receipt of request for conversion). | |
| V. INTERNATIONAL DEPOSITARY AUTHORITY | |
| Name: DSMZ-DEUTSCHE SAMMLUNG VON MIKROORGANISMEN UND ZELLKULTUREN GmbH Address: Mascheroder Weg 1b D-38124 Braunschweig | Signature(s) of person(s) having the power to represent the International Depositary Authority or of authorized official(s): <i>V. Weh</i> Date: 2000-10-06 |

¹ Where Rule 6.4 (d) applies, such date is the date on which the status of international depositary authority was acquired.

BUDAPEST TREATY ON THE INTERNATIONAL
RECOGNITION OF THE DEPOSIT OF MICROORGANISMS
FOR THE PURPOSES OF PATENT PROCEDURE

INTERNATIONAL FORM

Degussa-Hüls AG
Kantstr. 2


33790 Halle

VIABILITY STATEMENT

issued pursuant to Rule 10.2 by the

INTERNATIONAL DEPOSITARY AUTHORITY

identified at the bottom of this page

| | |
|---|--|
| I. DEPOSITOR | II. IDENTIFICATION OF THE MICROORGANISM |
| Name: Degussa-Hüls AG Kantstr. 2 Address: 33790 Halle | Accession number given by the INTERNATIONAL DEPOSITARY AUTHORITY: DSM 13762 Date of the deposit or the transfer ¹ : 2000-10-02 |
| III. VIABILITY STATEMENT | |
| The viability of the microorganism identified under II above was tested on 2000-10-04 ² . On that date, the said microorganism was <input checked="" type="checkbox"/> viable <input type="checkbox"/> no longer viable | |
| IV. CONDITIONS UNDER WHICH THE VIABILITY TEST HAS BEEN PERFORMED ⁴ | |
| | |
| V. INTERNATIONAL DEPOSITARY AUTHORITY | |
| Name: DSMZ-DEUTSCHE SAMMLUNG VON MIKROORGANISMEN UND ZELLKULTUREN GmbH Address: Mascheroder Weg 1b D-38124 Braunschweig | Signature(s) of person(s) having the power to represent the International Depositary Authority or of authorized official(s):  Date: 2000-10-06 |

¹ Indicate the date of original deposit or, where a new deposit or a transfer has been made, the most recent relevant date (date of the new deposit or date of the transfer).

² In the cases referred to in Rule 10.2(a) (ii) and (iii), refer to the most recent viability test.

³ Mark with a cross the applicable box.

⁴ Fill in if the information has been requested and if the results of the test were negative.

What is claimed is:

1. A process for the fermentative preparation of L-amino acids, in particular L-threonine, which comprises carrying out the following steps:
 - 5 a) fermentation of the microorganisms of the Enterobacteriaceae family which produce the desired L-amino acid and in which at least the poxB gene or nucleotide sequences which code for it are attenuated, in particular eliminated,
 - 10 b) concentration of the L-amino acid in the medium or in the cells of the bacteria and
 - c) isolation of the L-amino acid.
2. A process as claimed in claim 1, wherein L-threonine, L-valine or L-lysine is prepared.
- 15 3. A process as claimed in claim 1, which comprises employing microorganisms in which further genes of the biosynthesis pathway of the desired L-amino acid are additionally enhanced.
4. A process as claimed in claim 1, which comprises
20 employing microorganisms in which the metabolic pathways which reduce the formation of the desired L-amino acid are at least partly eliminated.
5. A process as claimed in claim 1, which comprises
25 attenuating, in particular eliminating, expression of the polynucleotide(s) which code(s) for the poxB gene.
6. A process as claimed in claim 1, which comprises reducing the regulatory and/or catalytic properties of the polypeptide (enzyme protein) for which the polynucleotide poxB codes.

7. A process as claimed in claim 1, which comprises fermenting, for the preparation of L-amino acids, microorganisms of the Enterobacteriaceae family in which one or more genes chosen from the group consisting of:
- 5
- 7.1 the thrABC operon which codes for aspartate kinase, homoserine dehydrogenase, homoserine kinase and threonine synthase,
- 7.2 the pyc gene which codes for pyruvate carboxylase,
- 10
- 7.3 the pps gene which codes for phosphoenol pyruvate synthase,
- 7.4 the ppc gene which codes for phosphoenol pyruvate carboxylase,
- 15
- 7.5 the pntA and pntB genes which code for transhydrogenase,
- 7.6 the rhtB gene which imparts homoserine resistance,
- 7.7 the mqo gene which codes for malate:quinone oxidoreductase,
- 20
- 7.8 the rhtC gene which imparts threonine resistance,
- 7.9 the thrE gene which codes for threonine export and
- 7.10 the gdhA gene which codes for glutamate dehydrogenase
- is or are enhanced, in particular over-expressed, at
- 25 the same time.
8. A process as claimed in claim 1, which comprises fermenting, for the preparation of L-amino acids, microorganisms of the Enterobacteriaceae family in

which one or more genes chosen from the group consisting of:

- 8.1 the tdh gene which codes for threonine dehydrogenase,
 - 5 8.2 the mdh gene which codes for malate dehydrogenase,
 - 8.3 the gene product of the open reading frame (orf) yjfA,
 - 8.4 the gene product of the open reading frame (orf) ytfP, and
 - 10 8.5 the pckA gene which codes for the enzyme phosphoenol pyruvate carboxykinase,
- is or are attenuated, in particular eliminated or reduced in expression, at the same time.
9. A process as claimed in claim 1 or 2, which comprises
15 employing, for the preparation of L-threonine, the strain MG442ApoxB transformed with the plasmid PMW218gdhA, shown in figure 2.
 10. A process as claimed in claim 1 or 2, which comprises
20 employing, for the preparation of L-threonine, the strain MG442ApoxB transformed with the plasmid PMW219rhtC, shown in figure 3.
 11. A process as claimed in claim 1 or 2, which comprises employing, for the preparation of L-lysine, the strain TOC21RApoxB.
 - 25 12. A process as claimed in claim 1 or 2, which comprises employing, for the preparation of L-valine, the strain B-12288ApoxB.
 13. A microorganism of the Enterobacteriaceae family which produces L-amino acids, in which the poxB gene or

nucleotides sequences which code for it are attenuated, in particular eliminated, and which have a resistance to α -amino- β -hydroxyvaleric acid and optionally a compensatable partial need for L-isoleucine.

- 5 14. The *Escherichia coli* K-12 strain MG442 Δ poxB deposited at the Deutsche Sammlung für Mikroorganismen und Zellkulturen (DSMZ = German Collection of Microorganisms and Cell Cultures, Braunschweig, Germany) under no. DSM 13762.
- 10 15. The plasmid pMAK705 Δ poxB, which contains parts of the 5' and of the 3' region of the poxB gene, corresponding to SEQ ID No. 3, shown in figure 1.
16. The plasmid pMW218gdhA shown in figure 2.
17. The plasmid pMW219rhtC shown in figure 3.
- 15 18. An isolated polynucleotide from microorganisms of the Enterobacteriaceae family, containing a polynucleotide sequence which codes for the 5' and 3' region of the poxB gene, shown in SEQ ID No. 4, in particular suitable as a constituent of plasmids for position-specific mutagenesis of the poxB gene.
- 20 19. A strain of the Enterobacteriaceae family which produces L-threonine and contains a mutation in the poxB gene, corresponding to SEQ ID No. 4.

Figure 1:

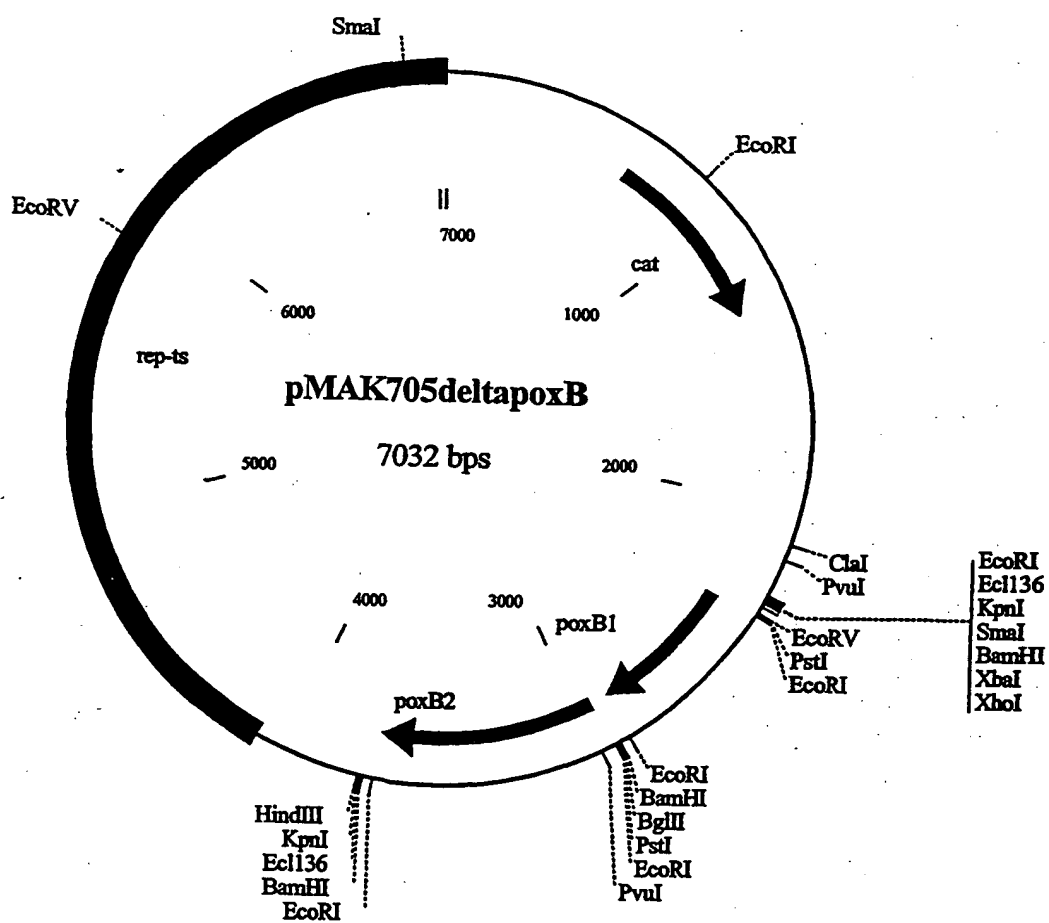


Figure 2:

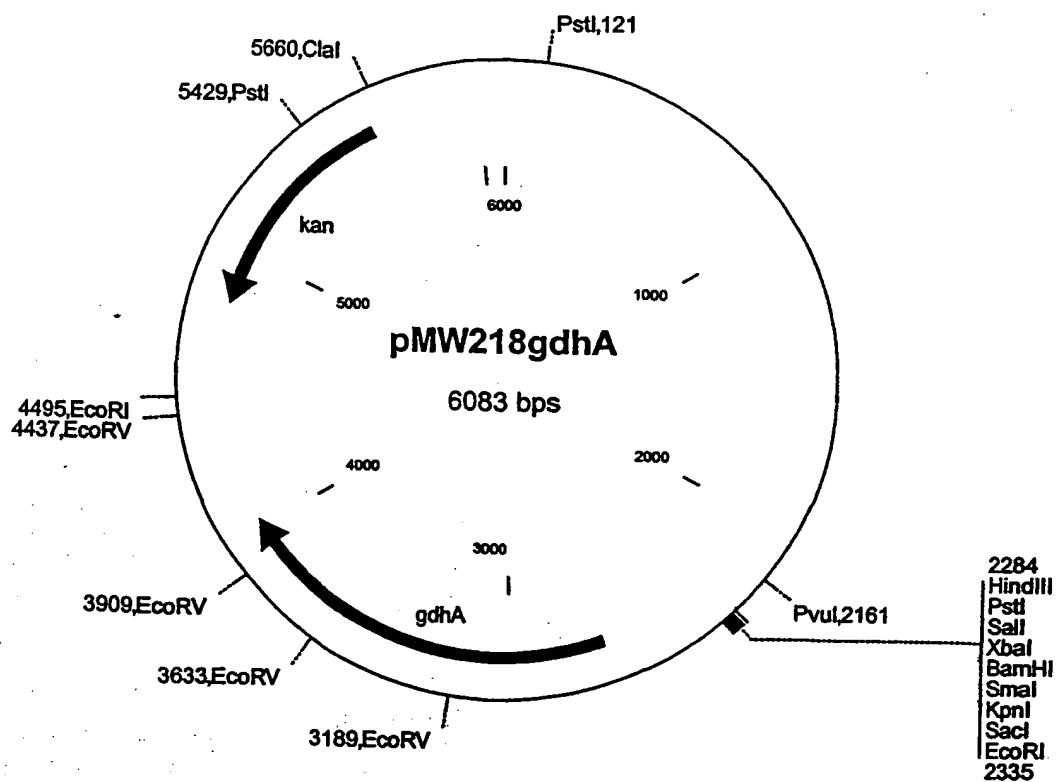
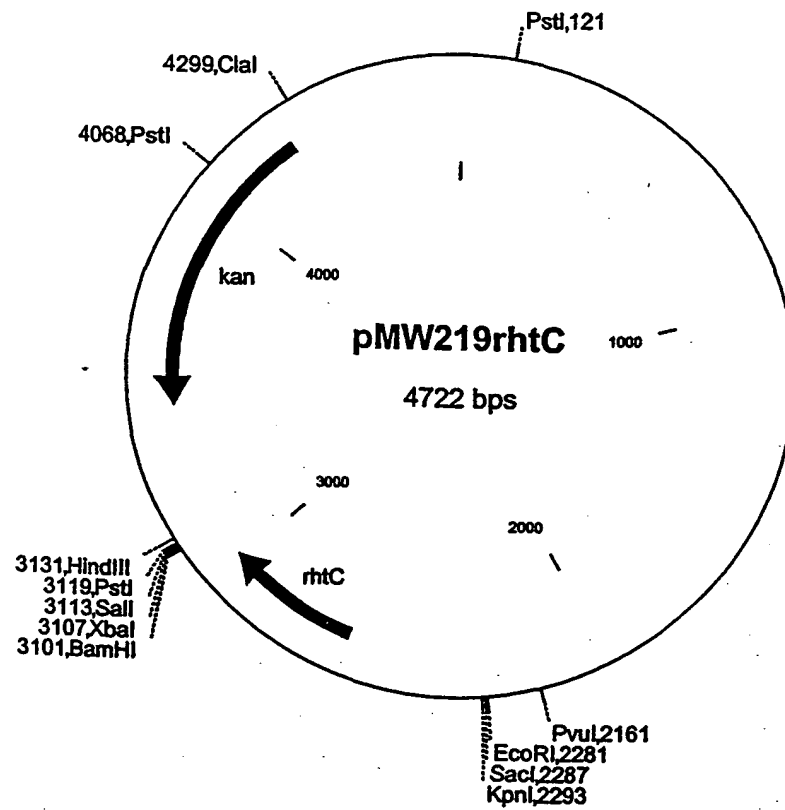


Figure 3:



SEQUENCE PROTOCOL

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5 <120> Process for the fermentative preparation of
L-amino acids using strains of the Enterobacteriaceae
family.

10 <130> 000613 BT

<140>

<141>

<160> 4

15 <170> PatentIn Ver. 2.1

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<211> 1719

20 <212> DNA

<213> Escherichia coli

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<221> CDS

25 <222> (1)..(1716)

<223> poxB

<400> 1

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1 5 10 15

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Gly Val Lys Arg Ile Trp Gly Val Thr Gly Asp Ser Leu Asn Gly Leu
20 25 30

40 agt gac agt ctt aat cgc atg ggc acc atc gag tgg atg tcc acc cgc 144
Ser Asp Ser Leu Asn Arg Met Gly Thr Ile Glu Trp Met Ser Thr Arg
35 40 45

45 cac gaa gaa gtg gcg gcc ttt gcc gct ggc gct gaa gca caa ctt agc 192
His Glu Glu Val Ala Ala Phe Ala Ala Gly Ala Glu Ala Gln Leu Ser
50 55 60

50 gga gaa ctg gcg gtc tgc gcc gga tgc tgc ggc ccc ggc aac ctg cac 240
Gly Glu Leu Ala Val Cys Ala Gly Ser Cys Gly Pro Gly Asn Leu His
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Leu Ile Asn Gly Leu Phe Asp Cys His Arg Asn His Val Pro Val Leu
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Ala Ile Ala Ala His Ile Pro Ser Ser Glu Ile Gly Ser Gly Tyr Phe
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Gln Glu Thr His Pro Gln Glu Leu Phe Arg Glu Cys Ser His Tyr Cys
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| | | | | | | | | | | | | | | | | | | |
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| | | Glu | Leu | Val | Ser | Ser | Pro | Glu | Gln | Ile | Pro | Gln | Val | Leu | Ala | Ile | Ala | |
| | | 130 | | | | | | 135 | | | | | 140 | | | | | |
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| | | | 195 | | | | | 200 | | | | | | 205 | | | | |
| | | ggc | agc | ggc | tgc | gcg | ggg | gcg | cat | aaa | gag | tta | gtt | gag | ttt | gcc | ggg | 672 |
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| | | | 210 | | | | 215 | | | | | | 220 | | | | | |
| 25 | | aaa | att | aaa | gcg | cct | att | gtt | cat | gcc | ctg | cgc | ggt | aaa | gaa | cat | gtc | 720 |
| | | Lys | Ile | Lys | Ala | Pro | Ile | Val | His | Ala | Leu | Arg | Gly | Lys | Glu | His | Val | |
| | | | 225 | | | | 230 | | | | | 235 | | | | | 240 | |
| 30 | | gaa | tac | gat | aat | ccg | tat | gat | gtt | gga | atg | acc | ggg | tta | atc | ggc | ttc | 768 |
| | | Glu | Tyr | Asp | Asn | Pro | Tyr | Asp | Val | Gly | Met | Thr | Gly | Leu | Ile | Gly | Phe | |
| | | | | | 245 | | | | | | 250 | | | | | 255 | | |
| 35 | | tcg | tca | ggt | ttc | cat | acc | atg | atg | aac | gcc | gac | acg | tta | gtg | cta | ctc | 816 |
| | | Ser | Ser | Gly | Phe | His | Thr | Met | Met | Asn | Ala | Asp | Thr | Leu | Val | Leu | Leu | |
| | | | | | 260 | | | | | 265 | | | | | 270 | | | |
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| | | Gly | Thr | Gln | Phe | Pro | Tyr | Arg | Ala | Phe | Tyr | Pro | Thr | Asp | Ala | Lys | Ile | |
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| | | att | cag | att | gat | atc | aac | cca | gcc | agc | atc | ggc | gct | cac | agc | aag | gtg | 912 |
| | | Ile | Gln | Ile | Asp | Ile | Asn | Pro | Ala | Ser | Ile | Gly | Ala | His | Ser | Lys | Val | |
| | | | 290 | | | | 295 | | | | | | 300 | | | | | |
| 45 | | gat | atg | gca | ctg | gtc | ggc | gat | atc | aag | tcg | act | ctg | cgt | gca | ttg | ctt | 960 |
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| 50 | | cca | ttg | gtg | gaa | gaa | aaa | gcc | gat | cgc | aag | ttt | ctg | gat | aaa | gcg | ctg | 1008 |
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| | | | |
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| | Phe Ala Ala Asp Asp Ala Ile Phe Thr Cys Asp Val Gly Thr Pro Thr | | |
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| | 435 440 445 | | |
| | atg aaa ctg cca gtg aaa att gtc gtc ttt aac aac agc gtg ctg ggc | 1392 | |
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| | Phe Val Ala Met Glu Met Lys Ala Gly Gly Tyr Leu Thr Asp Gly Thr | | |
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| | Glu Leu His Asp Thr Asn Phe Ala Arg Ile Ala Glu Ala Cys Gly Ile | | |
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| 35 | acg ggt atc cgt gta gaa aaa gcg tct gaa gtt gat gaa gcc ctg caa | 1536 | |
| | Thr Gly Ile Arg Val Glu Lys Ala Ser Glu Val Asp Glu Ala Leu Gln | | |
| | 500 505 510 | | |
| 40 | cgc gcc ttc tcc atc gac ggt ccg gtg ttg gtg gat gtg gtg gtc gcc | 1584 | |
| | Arg Ala Phe Ser Ile Asp Gly Pro Val Leu Val Asp Val Val Val Ala | | |
| | 515 520 525 | | |
| | aaa gaa gag tta gcc att cca ccg cag atc aaa ctc gaa cag gcc aaa | 1632 | |
| | Lys Glu Glu Leu Ala Ile Pro Pro Gln Ile Lys Leu Glu Gln Ala Lys | | |
| | 530 535 540 | | |
| 45 | ggg ttc agc ctg tat atg ctg cgc gca atc atc agc gga cgc ggt gat | 1680 | |
| | Gly Phe Ser Leu Tyr Met Leu Arg Ala Ile Ile Ser Gly Arg Gly Asp | | |
| | 545 550 555 560 | | |
| 50 | gaa gtg atc gaa ctg gcg aaa aca aac tgg cta agg taa | 1719 | |
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| | Pro Gly Asn Leu His 80 | Leu Ile Asn Gly 85 | Phe Asp Cys His Arg Asn His Val Pro Val Leu 95 |
| 15 | Ala Ile Ala 100 | Ala His Ile Pro Ser 105 | Ser Glu Ile Gly Ser Gly Tyr Phe 110 |
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| | Met Arg Lys 145 | Ala Val Leu Asn Arg Gly Val Ser Val Val Val Leu Pro 160 | |
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| 55 | Pro Leu Val 325 | Glu Lys Ala Asp Arg Lys Phe Leu Asp Lys Ala Leu 335 | |
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| 60 | Ser Glu Lys Ala Ile His Pro Gln Tyr Leu Ala Gln Gln Ile Ser His | | |

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| | Val Trp Ala Ala Arg Tyr Leu Lys Met Asn Gly Lys Arg Arg Leu Leu 385 390 395 400 | | |
| 10 | Gly Ser Phe Asn His Gly Ser Met Ala Asn Ala Met Pro Gln Ala Leu 405 410 415 | | |
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| 15 | Asp Gly Gly Phe Ser Met Leu Met Gly Asp Phe Leu Ser Val Val Gln 435 440 445 | | |
| | Met Lys Leu Pro Val Lys Ile Val Val Phe Asn Asn Ser Val Leu Gly 450 455 460 | | |
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| | Glu Leu His Asp Thr Asn Phe Ala Arg Ile Ala Glu Ala Cys Gly Ile 485 490 495 | | |
| 25 | Thr Gly Ile Arg Val Glu Lys Ala Ser Glu Val Asp Glu Ala Leu Gln 500 505 510 | | |
| | Arg Ala Phe Ser Ile Asp Gly Pro Val Leu Val Asp Val Val Val Ala 515 520 525 | | |
| 30 | Lys Glu Glu Leu Ala Ile Pro Pro Gln Ile Lys Leu Glu Gln Ala Lys 530 535 540 | | |
| 35 | Gly Phe Ser Leu Tyr Met Leu Arg Ala Ile Ile Ser Gly Arg Gly Asp 545 550 555 560 | | |
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| gcaatcacgt | tccggtactg | gcgattgccg | ctcatattcc | ctccagcgaa | attggcagcg | 300 |
| gctatttcca | ggaaaccac | ccacaagagc | tattccgcga | atgtagtcac | tattgcgagc | 360 |
| tggtttccag | cccggagcag | atcccacaag | tactggcgat | tgccatgcgc | aaagcgggtg | 420 |
| ttaaccgtgg | cgtttcggtt | gtcgtgttac | caggcgacgt | ggcggtaaaa | cctgcgccag | 480 |
| aagggggcaac | catgcaactg | tatcatgcgc | cacaaccagt | cgtagcgcgc | gaagaagaag | 540 |
| agttacgcaa | actggcgcaa | ctgctgcgtt | attccaggcc | taagggcgaa | ttccagcaca | 600 |
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| tccattggtg | gaagaaaaag | ccgatcgcaa | gtttctggat | aaagcgctgg | aagattaccg | 720 |
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| tggtacgcca | acggtgtggg | cggcacgtta | tctaaaaatg | aacggcaagc | gtcgctgtgt | 900 |
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Published:
— with international search report

(71) Applicant: DEGUSSA AG [DE/DE]; Bennigseplatz 1,
40474 Düsseldorf (DE).

(88) Date of publication of the international search report:
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(72) Inventors: RIEPING, Mechthild; Mönkebergstrasse 1,
33619 Bielefeld (DE). THIERBACH, Georg; Gunst-
strasse 21, 33613 Bielefeld (DE).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.



WO 02/036797 A3

(54) Title: PROCESS FOR THE FERMENTATIVE PREPARATION OF L-AMINO ACIDS USING STRAINS OF THE ENTEROBACTERIACEAE FAMILY

(57) Abstract: The invention relates to a process for the fermentative preparation of L-amino acids, in particular L-threonine, in which the following steps are carried out: a) fermentation of the microorganisms of the Enterobacteriaceae family which produce

INTERNATIONAL SEARCH REPORT

Int ional Application No

PCT/EP 01/11228

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C12N15/53 C12N15/52 C12N15/70 C12P13/08 C12N9/02
C12N1/21

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C12N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, BIOSIS, SEQUENCE SEARCH, CHEM ABS Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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- *P* document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

Z document member of the same patent family

Date of the actual completion of the international search

30 July 2002

Date of mailing of the international search report

14/08/2002

Name and mailing address of the ISA

European Patent Office, P.B. 5618 Patentlaan 2
NL - 2280 HV Rijswijk
Tel (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax (+31-70) 340-3016

Authorized officer

Douschan, K

INTERNATIONAL SEARCH REPORT

Int. Application No
PCT/EP 01/11228

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|-----------------------|
| A | CHANG Y-Y ET AL: "MOLECULAR CLONING, DNA SEQUENCING, AND ENZYMATIC ANALYSES OF TWO ESCHERICHIA COLI PYRUVATE OXIDASE MUTANTS DEFECTIVE IN ACTIVATION BY LIPIDS" JOURNAL OF BACTERIOLOGY, WASHINGTON, DC, US, vol. 167, no. 1, July 1986 (1986-07), pages 312-318, XP000987283 ISSN: 0021-9193 the whole document | 1-19 |
| A | GRABAU C ET AL: "MOLECULAR CLONING OF THE GENE (POXB) ENCODING THE PYRUVATE OXIDASE OF ESCHERICHIA COLI, A LIPID-ACTIVATED ENZYME" JOURNAL OF BACTERIOLOGY, WASHINGTON, DC, US, vol. 160, no. 3, December 1984 (1984-12), pages 1088-1092, XP000987282 ISSN: 0021-9193 the whole document | 1-19 |
| A | US 4 278 765 A (DEBAOV V. G. ET AL.) 14 July 1981 (1981-07-14) cited in the application the whole document | 1-19 |
| A | DATABASE BIOSIS 'Online! BIOSCIENCES INFORMATION SERVICE, PHILADELPHIA, PA, US; 1987 VAN DYK T K ET AL: "PLEIOTROPIC EFFECTS OF POX-A REGULATORY MUTATIONS OF ESCHERICHIA-COLI AND SALMONELLA-TYPHIMURIUM MUTATIONS CONFERRING SULFOMETURON METHYL AND ALPHA KETO BUTYRATE HYPERSENSITIVITY" Database accession no. PREV198784118407 XP002208065 abstract & JOURNAL OF BACTERIOLOGY, vol. 169, no. 10, 1987, pages 4540-4546, ISSN: 0021-9193 | 13,19 |
| A,P | WO 01 71012 A (DEGUSSA AG) 27 September 2001 (2001-09-27) claim 7 | 1-19 |
| A,P | EP 1 096 013 A (DEGUSSA G) 2 May 2001 (2001-05-02) claims 1-16 | 1-19 |

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 01/11228

| Patent document cited in search report | | Publication date | Patent family member(s) | Publication date |
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